Effects of b_0 errors/drift

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Suppose b_0 drifts by 1 unit, is left uncorrected, and consider two cases: (a) it drifts systematically by 1 unit in every dipole, (b) it drifts randomly in every dipole, with zero mean and rms of 1 unit...

(a) systematic drift of 1 unit means the bend field changes by 1 part in 10^4 and so is equivalent to an energy change of that amount. Thus, the radial position of the orbit would change according to the dispersion function in the Tevatron:

$$\Delta D_x \times (\Delta p/p) = (3\text{ m})(0.1 \times 10^{-3}) = 0.3\text{ mm}$$

as a typical value, with peaks of 0.5 mm at high dispersion locations. Currently, there is also vertical dispersion in the Tevatron due to the coupling problem, but it is 10 times smaller.

(b) random drift with rms $\Delta b_0^{(rms)} = 1$ unit generates a random closed orbit distortion which itself will have an rms value at a standard focusing quad location:

$$\Delta x_{rms} \approx \frac{\theta_0 \Delta b_0^{(rms)} \sqrt{\beta_0 \langle\beta\rangle}}{2|\sin\pi\nu|}\sqrt{\frac{N_{dip}}{2}} = \Delta b_0^{(rms)} \frac{\sqrt{\beta_0\langle\beta\rangle}}{2|\sin\pi\nu|}\sqrt{\frac{\theta_0^2 N_{dip}}{2}} = \Delta b_0^{(rms)} \frac{\sqrt{\beta_0\langle\beta\rangle}}{2|\sin\pi\nu|}\sqrt{\theta_0\pi}$$

and so for $\Delta b_0^{(rms)} = 1$ unit $= 0.1$ mrad, $\theta_0 = 2\pi/774 = 8$ mrad, $\beta_0 = 100$ m, and $\langle\beta\rangle \approx 55$ m, we get $\Delta x_{rms} \approx 0.6$ mm, with peak deviations, therefore, on the order of 1-1.5 mm.

For case (b), random displacements in the dipoles would not, in principle, produce a significant tune shift because of the zero mean. For case (a), I would estimate the tune shift as

$$\Delta\nu \approx \langle \beta\ \Delta x\ b_2 \rangle$$

which, using $\langle b_2 \rangle = 4$ units for scaling purposes, would give

$$\Delta\nu \approx (55\text{ m})(0.3\text{ mm})(0.4 \times 10^{-3}/(25.4\text{ mm}^2)) = 0.01.$$